



**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

# Ballistic Protection

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## Mission

- Mature Armor Systems from Technical Readiness Level (TRL) 4 to TRL 6 to fulfill ground vehicle Program Management (PM) needs.

## Base Armor

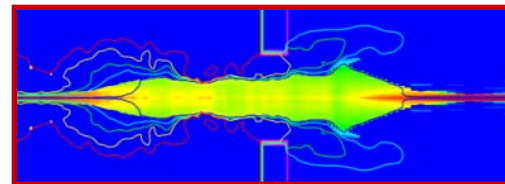
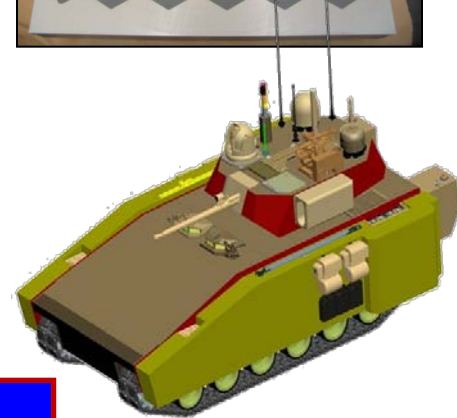
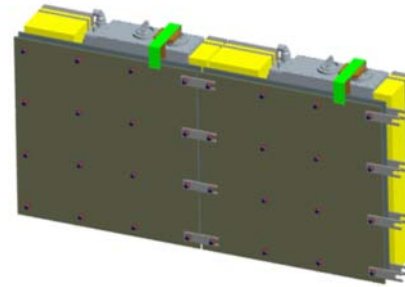
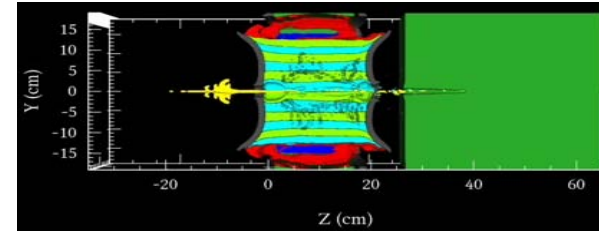
- Small Arms/Frag Opaque B-kits
- Medium Cal/Frag Opaque B-kits
- Transparent Armor



## Appliqué Armor (C-kit)

- Passive Multi-Threat
- Reactive Multi-Threat
- Active Multi-Threat

## Integration / Design Enablers

- Scalable, Modular & Common Armor System Integration Techniques
- Multifunctional Armors
- Modeling & Simulation
- Testing Capabilities



<div> <div>ARMOR INTEGRATION &amp; MATURATION</div> <div>↓</div> </div>	TRL	General Definition	Armor Package Definition	Industry Partnership
	4	Component validation in a lab environment	Armor meets ballistic performance (threat, number of shots, multi-hit shot spacing, velocity) at the <u>coupon level</u> .	Yes
	5 	Component validation in a relevant environment	Armor maintains ballistic performance at the <u>coupon level</u> after <u>exposure to relevant environments</u> or in packaged configurations.	Yes
	6 	Subsystem / system demonstration in a relevant environment	Armor maintains ballistic performance after <u>packaged/mounted</u> on a <u>vehicle-representative structure</u> and after <u>introducing relevant environments</u> and relevant threat engagements.	Yes

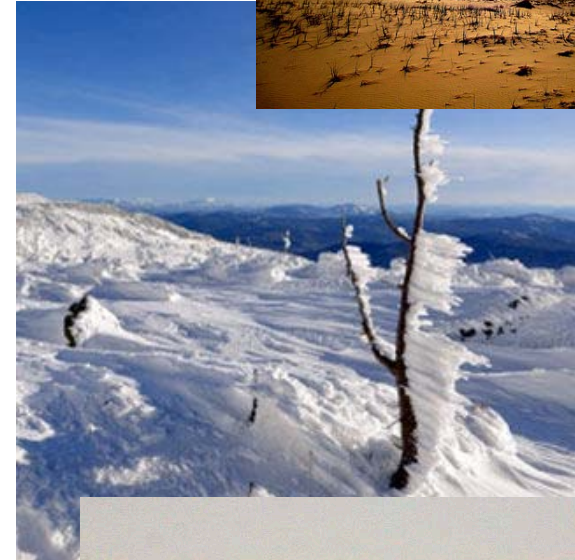
The following tests have been identified as potential tests that could be required for maturation of a new armor design. The tests required will be dependent on the materials and uniqueness of the armor design.

## MIL-STD 810

- Heat Loading
- Cold Loading
- Thermal Cycling
- Contamination by Fluids
- Solar Radiation
- Rain
- Humidity
- Salt Fog
- Sand & Dust
- Acidic Atmosphere
- Vibration
- Shock
- Fire, Smoke & Toxicity

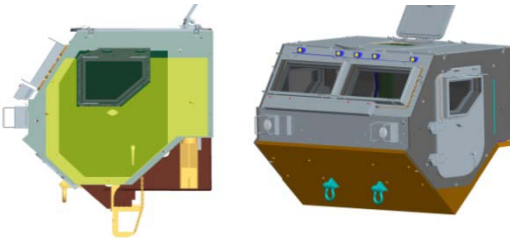
## ATPD 2352 (First Article)

- Allowable Defects
- Transmittance
- Haze
- Optical
- Chemical
- De-icing
- Humidity
- Abrasion
- Sun Exposure
- Weathering
- Ballistic (@ ambient temp)
- Temp (Shock, Low & High)
- Rock Strike / Low Impact

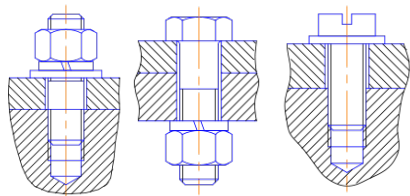




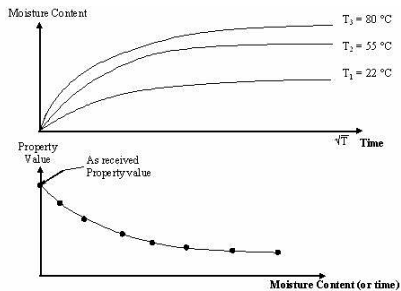
Modeling & Simulation  
and Design  
(TRL 5 & 6)



Reduce Ballistic Vulnerabilities



Integration Burden Mitigation /  
Ballistic Performance Design

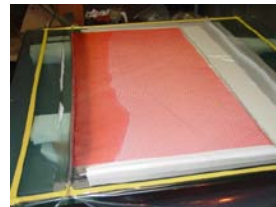


Environmental / Durability  
Simulations

Fabrication (TRL 4, 5 & 6)



Ceramics



Composites



Metallic



State-of-the-Art  
Combinations

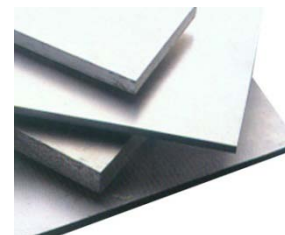
Coupon Level Ballistic  
Testing / Validation  
(TRL 4, 5 & 6)



Small and medium caliber  
ballistics / frag testing



Transparent Armor Testing



Opaque Armor Testing

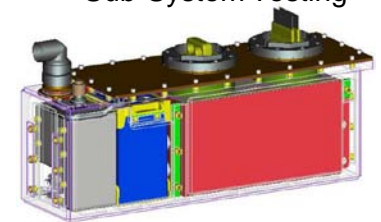
System / Sub-System  
Integration and Testing  
(TRL 6)



System Installation



Sub-System Testing



Integration of Enabling  
Technologies

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

Name	FY						Description
	11	12	13	14	15	16	
Advanced Combat Vehicle Armor Development (ACVAD)							<p>Reduced cost, lighter weight, extended multi-threat 2nd generation B and C combat armor systems:</p> <ul style="list-style-type: none"> <li>• B kit - encapsulated ceramics</li> <li>• C kit - passive, reactive &amp; electro-magnetic</li> <li>• Health monitoring</li> </ul>
Armor Development							<p>Research, development &amp; testing of armor system maturation enablers:</p> <ul style="list-style-type: none"> <li>• Emerging technologies</li> <li>• System engineering process</li> <li>• Standards (design, integration, test)</li> <li>• Manufacturing capabilities</li> <li>• Test &amp; evaluation of A &amp; B armor systems</li> </ul>
Transparent Armor (TA)							<p>Research, development &amp; testing of transparent armor:</p> <ul style="list-style-type: none"> <li>• Reduced interlayer de-bonding</li> <li>• Rock strike abatement</li> <li>• Lighter weight strike face &amp; interlayer</li> <li>• ATPD 2352 revisions</li> <li>• First article &amp; production quality control testing</li> </ul>

## Purpose:

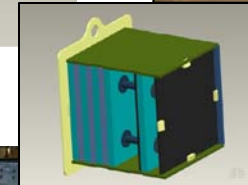
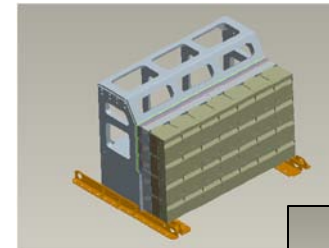
- Further mature and develop weight / space trades to reduce cost of the threshold CVAD armor for GCV
- Develop GCV objective threat armor system while meeting platform weight, space and cost goals
- Advance electro-magnetic armor systems maturity
- Develop smart armor with embedded, real-time health monitoring capability.

## Requirements:



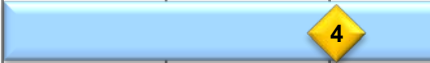


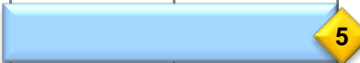

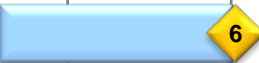

- Reduce CVAD cost, weight and/or space performance parameters while maintaining threshold threat protection.
- Transition objective threat TRL 6 armor systems to GCV in FY16 for block upgrade

## Products:



- Next generation combat armor systems demonstrated ballistic performance after packaged / mounted on a vehicle or representative structure and after introducing relevant environments
- Improved modeling & simulation tools for advanced threats and materials
- Efficient manufacturing processes for armor designs
- Embedded ultrasonic and optoelectronic sensors for health monitoring of ceramic and transparent armors





Milestone / Activity	FY12	FY13	FY14	FY15	FY16
Armor technology trade studies / continued threshold armor improvements and <u>maturation activities</u> (weight, space claim, performance vs cost). Determine armor <u>sensor options</u> per recipe and recognize defect identification.					
<u>Early performance evaluations</u> on down selected armor samples (risk mitigation test data). Evaluate results for thermal exposure, automotive inputs and ballistic multi hit shots. <u>Validate sensor integration</u> performance post vibration and environmental testing. Continue armor maturation activities and plan integration efforts.					
Armor development effort and <u>TRL 4 recipe transitions</u> . Level 1 & 2 B-kits and Level 0, 1 & 2 C-kits.					
Finalize <u>risk mitigation</u> evaluations on C-kit designs. Mature armor and <u>conduct TRL 5 testing</u> of armor designs (environmental & structural), conduct effect of defects study to determine how manufacturing defects change armor performance.					
<u>TRL 6 armor panel design</u> , attachments, integration, and system level test. Includes vibration, environmental & combined effects.					

## Armor TRL Requirements and Responsible Organization

		
<u>TRL 4</u> Coupon Level Performance	<u>TRL 5</u> Coupon Level Performance after Relevant Environment	<u>TRL 6</u> Armor System Performance after Relevant Environment

- ACVAD TRL 6 armor deliverables to GCV (with non integrated weight targets)
- TARDEC's armors will include metallic, composites, glass, ceramics, 3D weave, MMC and metallic encapsulated ceramics. C-kit armor defeat technologies include passive, reactive and electro-magnetic

Armor Description	Vehicle Area	CVAD Weight	ACVAD Weight	Total Cost
B-kit Level 1 Threshold	Side	xx psf	0% psf	-% Chg
B-kit Level 1 Objective	Side	N/A	0% psf	-% Chg
B-kit Level 2 Objective	Side	N/A	0% psf	-% Chg
C-kit Level 0 Passive	Side	xx psf	-21% psf	-% Chg
C-kit Level 1 Passive	Side	xx psf	-21% psf	-% Chg
C-kit Level 1 Active	Side	xx psf	-29% psf	-% Chg
C-kit Level 2 Objective	Side	N/A	0% psf	-% Chg

**ACVAD POC: Douglas Bertoia**

## Purpose:

Mature, integrate and demonstrate high energy / high power compact power control / distribution devices for defense applications

Electro-Magnetic Armor (EMA)

- Integrate and test the Pulse Power Unit with hybrid armor modules for low risk EMA
  - Testing to include durability, environmental and limited live fire testing
- Develop, integrate and test Power Brick based EMA with focus on operation, condition monitoring, and safety

High Energy Laser Tech Demo (HEL-TD)

- Develop, test and deliver Next Generation Laser Power Supply (reduced size, weight, increased power per kg)

## Customers:

- Electro-Magnetic Armor: PEO-GCS, GCV Increment 2
- High Energy Laser Programmable Pulse Power Supply (PPPS) : Space and Missile Defense Center (SMDC).

## Products:

Electro-Magnetic Armor (EMA)

- Silicon carbide based devices and components for EMA
- High Energy Density Capacitors for EMA
- 2nd Gen EMA Control Interface

High Energy Laser Tech Demo (HEL-TD) coordinated with SMDC

- Next Gen Laser Power Supply High Energy Laser Tech Demo
- New Advanced Pulse Forming Network (APFN) cards
  - 40% smaller than previous generation
  - Increase run time with less thermal management burden

## Payoff:

- Enable Electro-Magnetic Armors
- Enable future High Energy Laser (HEL) Demonstrations

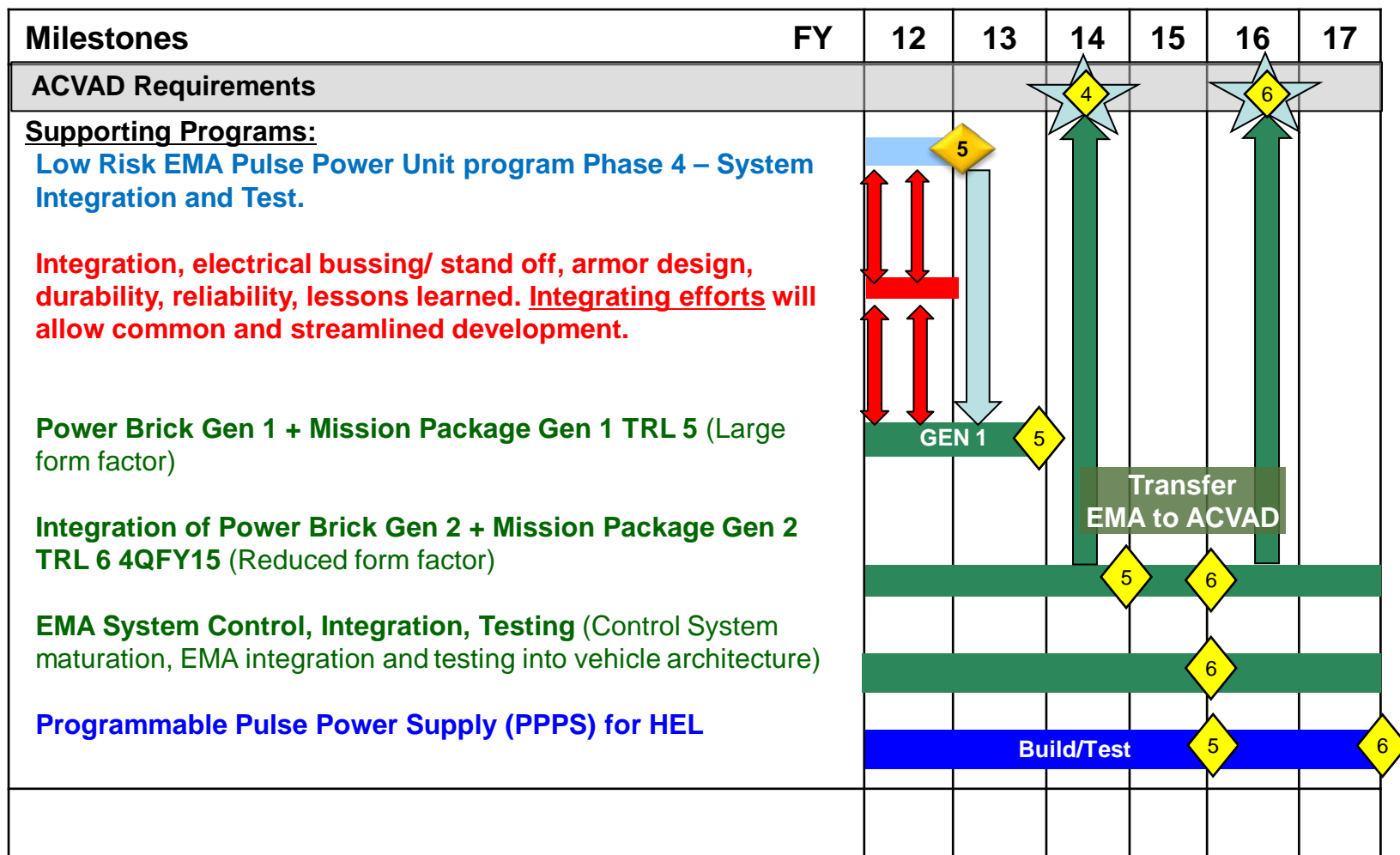
### **Electro-Magnetic Armor with Power Brick**

- Component & module development
- Integrated modules developed to fit in drift space
- Control system maturation



### **Laser Power Supply**

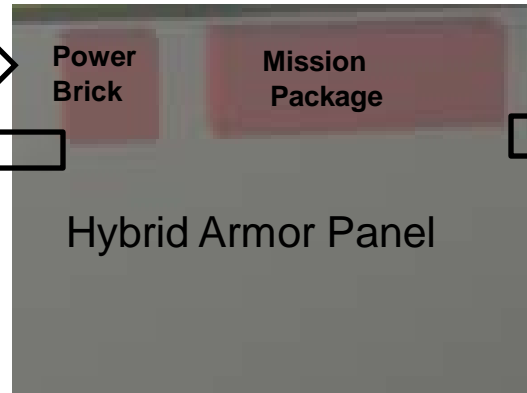




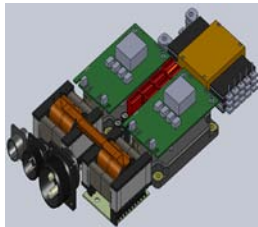




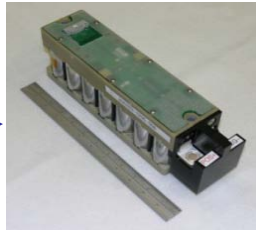
- Multi-hit system without recharging
- Provides support to meet emerging survivability threats
- Enables multi-threat armor systems



## Power Brick



DC to DC Charger  
28V to 600V  
Assembly starting  
in Summer 2011



Battery  
(Prototype)

## Mission Package



Pulse Charger  
600v to 10kV  
(Initial Design)













Capacitors  
High Energy Density  
(1.3J/cc)

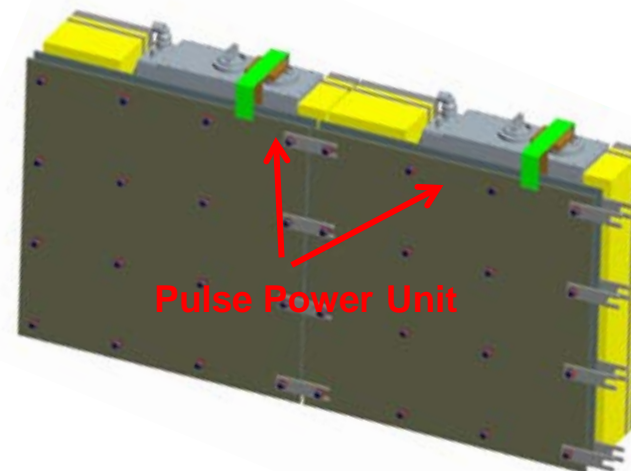


Solid State Switches  
Silicon, 2cm<sup>2</sup>, 12kA  
SiC, .73cm<sup>2</sup>, 5kA

EMA/Pulse Power POC: Joe White

Milestone Schedule	FY10	FY11	FY12
<b>Phase 1 – Armor Module Recipe Validation</b>			
<b>Phase 2 – Component Integration and Test</b>			
TARDEC design and build 1 <sup>st</sup> gen LR EMA			
Contractor design and develop Pulse Power System			
Test Series I – Ballistic (Single Modules)			
<b>Phase 3 – Subsystem Integration and Test</b>			
TARDEC design and build 2 <sup>nd</sup> gen LR EMA			
Test Series II – Environmental/Durability/Ballistic			
<b>Phase 4 – System Integration and Test</b>			
Test Series III –Ballistic (Multiple Modules)			

## TARDEC Armor System Modules



## Project Goals

Weight	xx psf	xx psf (integrated)	-10% psf (integrated w/ PPU)
TRL	4	4+	5

EMA/Pulse Power POC: Joe White

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

## **Purpose:**

- Development of opaque armors for the defeat of direct fire, IED, and Shape Charge Jet (SCJ) threats
- Manage ManTech efforts to reduce material and processing cost of advanced armor systems
- Fabricate sub-system and prototype system level armor packages
- Provide Subject Matter Expert (SME) support to PM offices and OGAs

## **Requirement:**

- Need for lightweight armor solutions for an increasingly weight burdened force
- Development of processes and techniques to lower cost of advanced armor systems
  - Technology is there, but not affordable
- Maturation of new armor solutions to defeat an ever changing threat set

## **Product:**

- Lightweight B-Kit and C-Kit armor solutions that provide increased protection and are affordable
- Matured multi-threat armor solutions that are able to withstand extreme environments
- Advanced integration techniques to reduce integration burden (**scalable, modular & common**) and minimize vehicle vulnerabilities



Focused Efforts	FY 12	FY 13	FY 14	FY 15	FY 16	FY 17
Receive/Develop advanced B-Kit recipe from Industry	4					
Design/Integrate/Mature B-Kit recipe and perform APS residual testing		5		6		
Receive/Develop advanced B-Kit and C-Kit recipes from Industry			4			
Design/Integrate/Mature B-Kit and C-Kit recipes				5		6
Fastening and joining research under ballistic loading conditions	Enabling Capability					
<b>Scalable, modular &amp; common</b> integration & best practices standards development	Enabling Capability					



## Needs

### – New alloys

- Aluminum
- Steel
- Ti

- Improved ballistic performance against both direct fire and fragmentation threats

### – Ceramics

- Silicon Carbide
- Boron Carbide
- Encapsulated

- Significant cost reductions and improved manufacturing
- Improved integration techniques to minimize additional burden and increase damage resistance

### – Manufacturing

- Build to print ceramics
- Advanced joining

- Automated assembly of custom ceramic parts
- Improved joining of thick section metallic (e.g. friction stir welding, laser beam welding)

### – Modeling and Simulation

- Ballistic (sub-system level)
- Material models
- Further code development

- Improved M&S for ballistic events at sub-system level focusing on fasteners and joints
- High strain rate materials properties

## **Purpose:**

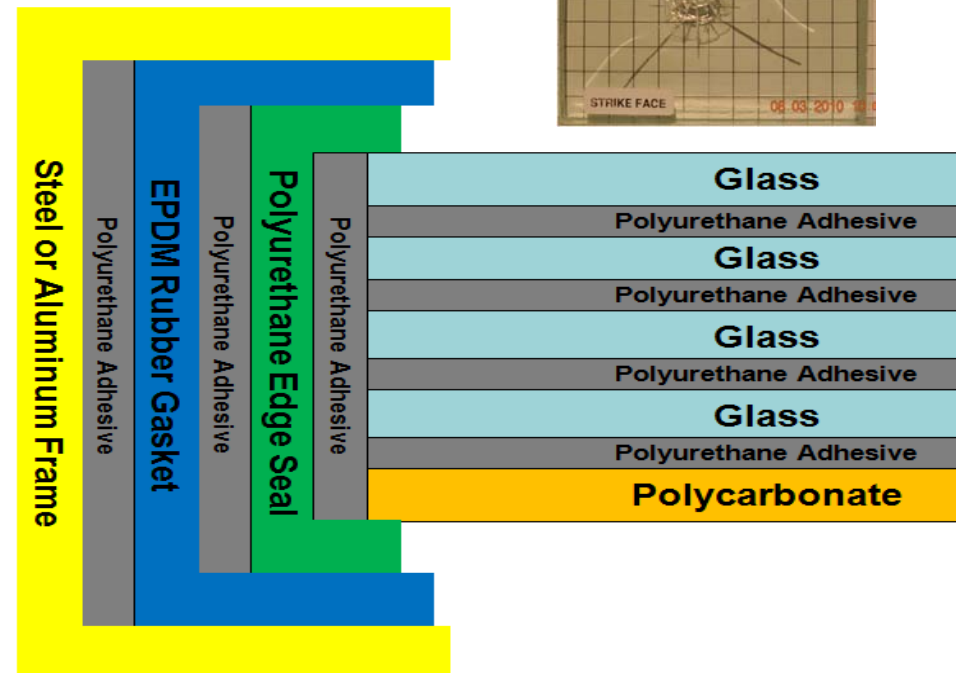
- Research and develop technologies and processes for improved performance and environmental stable transparent armor laminates
- Development of products and test procedures to improve rock-strike and delamination resistance
- Further refine ATPD 2352 to improve the overall quality of transparent armor purchased using the specification without additional cost to the Government

## **Requirement:**

- Transparent armor provides two main functions for the Warfighter
  1. Ballistic protection from incoming threats
  2. Ability to maintain Situational Awareness
- Must be robust enough to withstand low velocity impacts (e.g. rock-strike) and extreme temperature environments with minimal loss of above capabilities

## **Product:**

- Transparent armor laminates purchased by the Army will have improved rock-strike and environmental resistance
- Improved quality and consistency of transparent armor laminates
- Design guidance for transparent armor cross-sections and integration schemes



Focused Efforts	FY 12	FY 13	FY 14
Materials and Processing	Effects of <u>autoclave processing</u> temperature and pressure on ballistic performance	Investigation of <u>novel polycarbonate</u> materials and their effect on ballistic performance	Develop TA solution with <u>improved rock-strike resistance</u> and environmental performance
Integration Methods	Investigation of various <u>potting compounds</u> and TA coupon <u>edge wraps</u> for improved weather -ability	Investigate <u>novel integration techniques</u> and develop a recommended <u>maximum torque</u> and bolt pattern for TA	
Modeling and Simulation	Effects of <u>polycarbonate thickness and placement</u> in TA cross-section on residual part stress. Obtain high strain rate <u>materials properties</u> for polyurethane.	Effects of <u>size and shape</u> of TA on residual stress. Effect of <u>interlayer thickness</u> of residual stress and ballistic performance	Utilize <u>modeling and simulation</u> for low velocity impacts (rock-strike) investigations

## Needs

### – Glass

- Water white
- Glass ceramic
- Fused silica

- Improved impact and damage resistance
- Damage localization of low velocity impacts.

### – Ceramics

- Spinel
- AlON

- Significant cost reductions without performance loss
- Decrease in haze; improved luminous transmission

### – Interlayer Materials

- Polyurethane
- Other?

- Improved adhesion and “compliance”
- “Better” material for wide temperature range

### – Backing Materials

- Polycarbonate
- Thin section Glass
- Other?

- Improved abrasion and chemical resistance
- Improved ballistic performance at low temps



# Conclusion

- Who we are.
- What our mission is.
- How we plan.
- What we are investing in.
- When we plan to work these efforts.
- Ideas on how you can help us help the Warfighter.



*This is the first of an annual event.....It may not be perfect, so we want the feed back to help us help you.*

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